INTEGRATED EXPERIMENTAL AND SIMULATION ANALYSIS OF STRESS AND STRAIN PARTITIONING IN DUAL PHASE STEEL

D. Raabe, Max-Planck-Institut für Eisenforschung GmbH, 40237 Düsseldorf, Germany
raabe@mpie.de
C. Tasan, Massachusetts Institute of Technology, DMSE, Cambridge, Massachusetts, 02139, USA
M. Diehl, Max-Planck-Institut für Eisenforschung GmbH, 40237 Düsseldorf, Germany
P. Shantraj, Max-Planck-Institut für Eisenforschung GmbH, 40237 Düsseldorf, Germany
L. Morsdorf, Max-Planck-Institut für Eisenforschung GmbH, 40237 Düsseldorf, Germany
Y. Naunheim, Max-Planck-Institut für Eisenforschung GmbH, 40237 Düsseldorf, Germany
F. Roters, Max-Planck-Institut für Eisenforschung GmbH, 40237 Düsseldorf, Germany

Key Words: dual phase steel, micromechanics, martensite, crystal plasticity, simulation

The mechanical behavior of multiphase steels is governed by the microscopic strain and stress partitioning behavior among microstructural constituents [1-3]. However, due to limitations in the characterization of the partitioning that takes place at the submicron scale, microstructure optimization of such alloys is typically based on evaluating the averaged response, referring to, for example, macroscopic stress–strain curves. Here, a coupled experimental–numerical methodology is presented and discussed to strengthen the integrated understanding of the microstructure and mechanical properties of complex alloys, enabling joint analyses of deformation-induced evolution of the microstructure, and the strain and stress distribution therein, down to submicron resolution. From the experiments, deformation-induced evolution of (i) the microstructure, and (ii) the local strain distribution are concurrently captured, employing in situ secondary electron imaging and electron backscatter diffraction (EBSD) (for the former), and microscopic-digital image correlation (for the latter) [3,4]. From the simulations, local strain as well as stress distributions are revealed, through full-field crystal plasticity (CP) simulations conducted with the advanced DAMASK spectral solver suitable for heterogeneous materials [5,6]. The simulated model is designed directly from the initial EBSD measurements, and the phase properties are obtained by additional inverse CP simulations of nanoindentation experiments carried out on the original microstructure. The experiments and simulations demonstrate good correlation in the proof-of-principle study conducted here on a martensite–ferrite dual-phase steel, and deviations are discussed in terms of opportunities and limitations of the techniques involved.

1. C.C. Tasan et al. Strain localization and damage in dual phase steels investigated by coupled in-situ deformation experiments and crystal plasticity simulations, International Journal of Plasticity,63,198-210,2014
2. C.C. Tasan et al. An overview of dual-phase steels: advances in microstructure-oriented processing and micromechanically guided design, Annual Review of Materials Research,45,391-431,2015
3. D. Yan et al. High resolution in situ mapping of microstrain and microstructure evolution reveals damage resistance criteria in dual phase steels,Acta Materialia,96,399-409,2015
4. C.C. Tasan et al. Integrated experimental–simulation analysis of stress and strain partitioning in multiphase alloys,Acta Materialia,81,,386-400,2014
5. F. Roters, et al. 2012, DAMASK: The Düsseldorf Advanced Material Simulation Kit for studying crystal plasticity using an FE based or a spectral numerical solver, in Procedia IUTAM, Vol. III, pp. 3–10, Elsevier, Amsterdam.
6. https://damask.mpie.de